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The University of Texas at Austin

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ONR Basic Research Program: Summary and Bibliographies

Final Report under Grant N00014-90-J-0280
21 March 1994 - 31 August 1995

Thomas G. Muir and Elaine C. Frazer

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13. ABSTRACT (Maximum 200 words)

The Office of Naval Research (ONR) sponsored the Basic Research Program, a discretionary grant program for the purpose of giving university laboratory directors freedom to develop and apply their resources to basic research problems of naval relevance, which might not be known or appreciated by others in the community. Program guidelines included (1) involvement of students and faculty and (2) initiation of research in areas that could transition into either core or special research initiative (SRI) programs at ONR.

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PREFACE

This is the final report on work that Applied Research Laboratories, The University of Texas at Austin (ARL:UT), was tasked to perform under Grant N00014-90-J-0280.

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1. INTRODUCTION

The subject grant was originally issued on 21 March 1994 in response to Applied Research Laboratories, The University of Texas at Austin (ARL:UT), proposal P-1612 dated 6 July 1993.[1] This grant was funded out of the Office of the Chief of Naval Research (ONR) discretionary block for support of this laboratory as well as the following laboratories: Applied Research Laboratory, Pennsylvania State University (ARL/PSU); Applied Physics Laboratory, University of Washington (APL:UW); and Marine Physics Laboratory, Scripps Institution of Oceanography, University of California at San Diego (MPL:SIO:UCSD). This block was originally administered by ONR Code 324OA, Dr. Mohsen Badiey. Dr. Jeffrey Simmen took over from Dr. Badiey in 1994. The purpose of the discretionary grant program is to give the laboratory directors freedom to develop and apply their resources to basic research problems of naval relevance, which may not be known or appreciated by others in the community. The guidelines of the program include (1) involvement of student and faculty and (2) initiation of research in areas that could transition into either core or special research initiative (SRI) programs at ONR.

Support for ARL:UT in FY94 was based on six research problems, funded as shown in Table 1.1. This includes the fourth modification of the grant, issued on 24 January 1995 in response to ARL:UT proposal P1612(Rev.),[2] which substituted tasking for the first task listed below.

Table 1.1

Research Project	Principal Investigator	Funding
Fault Induced Vibration in Centrifugal and Axial-Flow Compressors	Dr. Kevin Baugh	$40K
High School Apprenticeship Program	Dr. Tom Muir	$35K
Combustive Sound Source	Mr. Preston Wilson and Dr. Janet Ellzey	$72K

Investigation of Shock/Vortex Interactions	Dr. Janet Ellzey	$51K
A Study of Sporadic E and Traveling Ionospheric Disturbances in a Mid-Latitude Ionosphere	Dr. Jeffrey Cook	$56K
Acoustic Agglomeration of Particulates for Pollution Abatement and Material Science Applications	Dr. O. A. Ezekoye	$65K
Shallow Water Acoustics	Dr. James TenCate	$81K

Modification 2, issued on 20 September 1994 in response to ARL:UT proposal P-1629 dated 17 February 1994,[3] added an additional $8.5K to the High School Apprenticeship Program.

Statistics on projects, students, faculty, etc., for the duration of this grant are shown in Table 1.2.

Table 1.2
ONR "ARL" Program

Purpose:

- Seed money - new 6.1 research
- Support UT professors and students on problems of naval relevance
- Support High School Apprenticeship Program

Administration:

- Dr. Jeffrey Simmen, ONR 1125OA
- Individual ONR project officers
- ARL:UT IR&D coordinator

	FY89	FY90	FY91	FY92	FY93	FY94
$K	133	299	310	348	370	400
No. of active projects	11	5	6	7	8	7
No. of students	11	5	6	7	6	8
No. of faculty	9	4	5	6	4	6

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2. RESEARCH RESULTS

The following bibliographical information summarizes the scientific results produced under this grant. We included work that may have begun under the preceding ONR discretionary grant, but was either finished or reported during the subject grant.

2.1 ARCHIVAL PUBLICATIONS

Bibliographical data are presented here, as well as the abstract of each paper that appeared in refereed journals. Also included are publications that have been submitted but are still in the journal editing process.

1. Ellzey, Janet L., Michael Henneke, J. Michael Picone,* and Elaine S. Oran* (*Naval Research Laboratory), "The Interaction of a Shock with a Vortex: Shock Distortion and the Production of Acoustic Waves," *Physics of Fluids,* **1**, 1 January 1995.

   Numerical simulations of a shock interacting with a compressible vortex are presented for shocks and vortices of various relative strengths. The simulations show the effects of the vortex on the shock structure and the structure of the acoustic field generated by the shock-vortex interaction. A relatively weak vortex perturbs the transmitted shock only slightly, whereas a strong vortex leaves the transmitted shock with a structure corresponding to either a regular or Mach reflection. The acoustic wave generated by the interaction consists of two components: a "quadrupolar" component produced by the initial shock-vortex interaction and the complex reflected shock system. When these waves merge, they form the asymmetric structure seen in experiments.

2. Cook, Jeffrey A., and Sigrid Close, "An Investigation of TID Evolution Observed in MACE '93 Data," *Ann. Geophysicae,* **13**, 1995.

Analysis of the total electron content (TEC) data and reconstructed tomographic images from the Mid-America CIT (computerized ionospheric tomography) Experiment (MACE '93) is presented with the intent of examining and characterizing ionospheric irregularities. The TEC data and tomographic images are examined for structure and irregularities on top of the smooth background data. Structures seen in the TEC data by neighboring receivers over a single transit pass are then correlated to obtain information about the approximate size and location of the structure. An attempt is made to analyze temporal and spatial evolution of structures from the TEC data using sequential satellite passes. The tomographic images generated from the TEC data are then examined for similar structures, with structure characteristics such as structure size and degree of electron density enhancement and depletion considered.

3. Manoucheri, M., and O. A. Ezekoye, "Polystyrene Soot Agglomeration Enhancement in an Ultrasonic Acoustic Field," *Journal of Hazardous Waste and Hazardous Materials*, **13**(1), 1996.

One approach to controlling the aerosol size distribution for a variety of applications is the use of acoustic/sonic aerosol agglomeration. Intense acoustic fields have been shown to induce large (as compared to passive processes) relative particle velocities which enhance particle collision frequencies. In this paper, the evolution of aerosol distributions in an intense acoustic field is examined. The particle size distribution is measured as a function of aerosol loading and acoustic field specification. Polystyrene foam fuel samples are burned in a static chamber with final soot mass loading of approximately 1.0 g/m^3. An array of piezo-electric acoustic transducers operated at approximately 20 kHz forms one wall of the chamber. Both laser extinction and inertial impactor measurements

were used to determine the effectiveness of the acoustic field in shifting the size distribution of the soot agglomerates.

2.2 NON-ARCHIVAL PUBLICATIONS

Bibliographical data and abstracts for papers that appeared in non-refereed publications, such as the proceedings of symposia, are presented here, along with the dates, location, host organization, and special topic of the publication.

1. Smith, Craig C., Ryan H. Holmes, and R. Joe Thornhill, "Time Aliasing to Reduce Frequency Leakage When Digitally Processing Acoustic, Shock, and Vibration Signals," in *Proceedings of the Third International Congress on Air- and Structure-Borne Sound and Vibration*, Vol. 2.

2. Pasanen, E. G., J. D. Travis, and R. J. Thornhill, "Wavelet-Type Analysis of Transient-Evoked Otoacoustic Emissions," in *Proceedings of the 31st Annual Rocky Mountain Bioengineering Symposium and 31st International ISA Biomedical Sciences Instrumentation Symposium*, 22-23 April 1994, Kansas State University, Manhattan, Kansas.

3. Constable, R., D. R. Carpenter, and R. J. Thornhill, "Time-Frequency Analysis of the Surface EMG during Maximum Height Jumps under Altered-G Conditions," in *Proceedings of the 31st Annual Rocky Mountain Bioengineering Symposium and 31st International ISA Biomedical Sciences Instrumentation Symposium*, 22-23 April 1994, Kansas State University, Manhattan, Kansas.

4. Wilson, Preston S., and Janet L. Ellzey, "Experimental Investigation of the Combustive Sound Source," in *Proceedings of the 23rd Meeting of The Technical Cooperation Program (TTCP) Subgroup G, Technical Panel*

GTP-9, Sonar Technology, 8 November 1994, Auckland, New Zealand (Defence Scientific Establishment, Auckland, New Zealand), Vol. 1.

2.3 COMPLETED DISSERTATIONS AND THESES

Bibliographical information on these academic documents is presented here. It should be noted that each of the graduates is a U.S. citizen, and each is a potential candidate for a leadership role in the conduct of future naval research and development.

1. Close, Sigrid (M.A., Physics, December 1994), "An Investigation of Atmospheric Gravity Waves and Traveling Ionospheric Disturbances Using Transit Dual Frequency Multi-Station Doppler Data."

2. Henneke, Michael R. (M.S., Engineering, December 1994), "A Study of Shock/Vortex Interaction."

3. Manoucheri, Michael P. (M.S., Engineering, August 1995), "Investigation of Acoustic Agglomeration in a Three Dimensional Standing Wave Field."

2.4 DISSERTATIONS AND THESES INITIATED

This project was initiated under the subject contract and is listed below. Due to the aforementioned change in primary guidelines, the project has now been reassigned to other funding sources, including ARL:UT Independent Research and Development (IR&D) funds.

1. Neal, Debra Leigh, "Experimental Identification of Rotating Stall in an Axial Flow Compressor," M.S. in Aerospace Engineering.

2.5 PAPERS PRESENTED AT MEETINGS

Titles, authors, and meeting data for papers presented at meetings are listed below. This listing does not include papers presented at meetings which have subsequently been issued as archival papers. Most, if not all, of the papers listed below will also be issued as archival papers. The presentation of scientific papers at meetings is a give-and-take process that enables the authors to receive criticism, comments, and an exchange of information that sharpens the work perspective and its ultimate relevance, prior to submission as an archival contribution.

1. Smith, Craig C., Ryan H. Holmes, and R. Joe Thornhill, "Time Aliasing to Reduce Frequency Leakage When Digitally Processing Acoustic, Shock, and Vibration Signals," presented at Third International Congress on Air- and Structure-Borne Sound and Vibration, 13-15 June 1994.

2. Pasanen, E. G., J. D. Travis, and R. J. Thornhill, "Wavelet-Type Analysis of Transient-Evoked Otoacoustic Emissions," presented at the 31st Annual Rocky Mountain Bioengineering Symposium and 31st International ISA Biomedical Sciences Instrumentation Symposium, 22-23 April 1994, Kansas State University, Manhattan, Kansas.

3. Constable, R., D. R. Carpenter, and R. J. Thornhill, "Time-Frequency Analysis of the Surface EMG during Maximum Height Jumps under Altered-G Conditions," presented at the 31st Annual Rocky Mountain Bioengineering Symposium and 31st International ISA Biomedical Sciences Instrumentation Symposium, 22-23 April 1994, Kansas State University, Manhattan, Kansas.

4. Wilson, Preston S., and Janet L. Ellzey, "Experimental Investigation of the Combustive Sound Source," 23rd Meeting of The Technical Cooperation Program (TTCP) Subgroup G, Technical Panel GTP-9, Sonar Technology, Auckland, New Zealand, 8 November 1994.

5. Ellzey, J. L., and M. R. Henneke, "The Shock-Vortex Interaction: Shock Distortion and Formation of the Acoustic Wave," Fluid Dynamics Section of the American Physical Society, 20-22 November 1994, Atlanta, Georgia.

6. Ellzey, Janet L., Preston S. Wilson, and Thomas G. Muir, "The Combustive Sound Source: Combustion and Bubble Dynamics Theory and Experiment," 128th Meeting of the Journal of the Acoustical Society of America, 28 November 1994, Austin, Texas.

7. Manoucheri, M., and O. A. Ezekoye, "Acoustic Agglomeration," Joint Central and Western States Section Meeting of the Combustion Institute, April 1995, San Antonio, Texas.

8. Ezekoye, O. A., and M. Manoucheri, "Polystyrene Soot Agglomeration Enhancement in an Ultrasonic Acoustic Field," The Fourth International Congress on Toxic Combustion Byproducts, June 1995, Berkeley, California.

9. Ellzey, J. L., "The Shock-Vortex Interaction: Relationship between Vortex Compression and the Acoustic Wave," Invited Lecture, The Shock-Vortex Workshop, 5-9 September 1995, Tokyo Denkai University, Tokyo, Japan.

10. Close, Sigrid, Gary S. Bust, and Jeffrey A. Cook, "Parameter Estimations of TIDS Using MACE '93 Data," National Meeting of the International Union of Radio Science, 3-7 January 1995, Boulder, Colorado.

2.6 ARL:UT REPORTS

In addition to the archival papers, dissertations, theses, and other highly valued scientific documents cited above, there is a very real and important need for the publication of a variety of reports that are useful in the conduct of work.

1. Constable, R., D. R. Carpenter, and R. J. Thornhill, "Time-Frequency Analysis of the Surface EMG during Maximum Height Jumps under Altered-G Conditions," Applied Research Laboratories Technical Preprint No. 94-21 (ARL-TP-94-21), Applied Research Laboratories, The University of Texas at Austin, 23 May 1994.

2. Pasanen, E. G., J. D. Travis, and R. J. Thornhill, "Wavelet-Type Analysis of Transient-Evoked Otoacoustic Emissions," Applied Research Laboratories, Technical Preprint No. 94-20 (ARL-TP-94-20), Applied Research Laboratories, The University of Texas at Austin, 23 May 1994.

3. Muir, Thomas G., and Elaine C. Hackert, eds., "The Department of Defense Science and Engineering Apprenticeship Program for High School Students, Summer Program 1994," Applied Research Laboratories Technical Report No. 94-24 (ARL-TR-94-24), Applied Research Laboratories, The University of Texas at Austin.

2.7 DoD SCIENCE AND ENGINEERING APPRENTICESHIP PROGRAM

The purpose of the apprenticeship program is to provide outstanding recent high school graduates with hands-on experience in the stimulating research environment and encourage them to pursue careers in the science and engineering disciplines, particularly in those areas related to the needs of the Department of Defense. Students were selected for this program on the basis of their academic records, scholastic aptitude test results, and applications. Each student was assigned to a research project to be performed under the

supervision of a research staff member at ARL:UT. At the end of the apprenticeship in mid-August, students gave oral presentations, using visual aids, for the Laboratories' directors, and prepared short technical papers summarizing their project results. The annual report included technical papers by the following student authors, whose abstracts appear below. Editing of the abstracts was minimal to preserve their originality of expression.

1994 Participants

Kenneth Baker	UQN-4 Depth Sounder Data Collection and Analysis
Carolina Duran	A Study of Baseline Dependent Errors on Realtime Ambiguity Resolution Techniques
Audrey Fant	An Assessment of GPS Data Processing Techniques for High Accuracy Surveying
Molly Frohlich	Distribution of Organically Generated Bubbles in Tank Sediment
Luke (Tan-Hsin) Fu	Non-Destructive Testing of Metallic Specimens Using Polyspectral Analysis
Edward Hou	Aerosol Agglomeration Transducers
Mokhtar Maamar-Tayeb	Passive Detection and Localization of Acoustic Sources Using the Hough Transform and Broadband Crosscorrelation
Anna Mitros	Measurements of Source Level in a Reverberant Underwater Environment
Jamie Margaret Shorey	Construction of a Parabolic Reflector from a Spinning Liquid
Nicholas Tornow	Audio Simulations of Sonar Bottom Backscattering Using Head-Related Transfer Functions

Abstracts of Apprenticeship Reports

1. Kenneth Baker. UQN-4 Depth Sounder Data Collection and Analysis.

In March 1994, the Navy conducted sea tests over the Eleuthera Test Range using the hydrographic data recording system (HDRS) with a UQN-4 depth sounder. Data collected from these tests allowed an evaluation of UQN-4 performance and the investigation of acoustic and signal processing techniques, which may then supplement the UQN-4 hardware to improve its performance. This report discusses the data collection equipment, algorithms for calculating errors and uncertainties for both depth and position, methods for calculating depth and signal-to-noise ratio from the analog waveforms, and the results of applying these algorithms to the sea test data.

2. Carolina Duran. A Study of Baseline Dependent Errors on Realtime Ambiguity Resolution Techniques.

Precise and accurate positioning has been a longtime goal of science and engineering. The Global Positioning System (GPS) is making this goal achievable. For the past few years, Applied Research Laboratories, The University of Texas at Austin (ARL:UT), has been testing the accuracy and precision of numerous GPS systems and applications. As a high school apprentice at ARL:UT, I had the opportunity to learn about GPS and to work with data collected from this system. My project included the examination of GPS data processed through the ARL:UT-developed realtime antenna array positioning (RAAP) system software. I studied baseline-dependent errors on realtime ambiguity resolution techniques and their possible application to the development of a portable impact location system (PILS).

3. Audrey Fant. An Assessment of GPS Data Processing Techniques for High Accuracy Surveying.

ARL:UT, in cooperation with the Defense Mapping Agency (DMA), is currently using Global Positioning System (GPS) technology to develop a method of obtaining millimeter-level positioning accuracy for the high speed sled track (HSST) at Holloman Air Force Base in New Mexico. This ten-mile rail track is used to calibrate inertial navigation systems (INS) used on high dynamic platforms, such as missiles and high performance aircraft. The DMA currently uses conventional surveying methods, which are time consuming, to survey over 500 benchmarks along the sled track with an accuracy of one millimeter. This process takes approximately one year to complete a single survey of the sled track. The goal of this effort is to determine if a GPS-based system could be used to replace existing surveying methods.

4. Molly Frohlich. Distribution of Organically Generated Bubbles in Tank Sediment.

This study will investigate the location of bubbles of biogenic origin, which have formed beneath the sediment of a freshwater laboratory tank. The bubbles have high levels of nitrogen and are thought to be produced by denitrifying bacteria, which are facultative anaerobes. By collecting the interstitial water with syringes and analyzing its dissolved oxygen content with an oxygen electrode, we will determine at which layer the denitrifiers can reside. Because the sediment is oxidic and there is little evidence of vertical stratification, we speculate that the bacteria live in anoxic microniches in no particular layer.

5. Luke (Tan-Hsin) Fu. Non-Destructive Testing of Metallic Specimens Using Polyspectral Analysis.

Tiny, hairline cracks found in the metallic framework of aircraft, submarines, and other military vehicles, as well as commercial modes of transportation, if left undetected to develop into larger fissures can cause dangerous and sometimes deadly disasters. Presently, conventional methods of

detection are still being employed that consist of merely routine visual checks by maintenance crews. However, as the cost of building such crafts rapidly increases, more reliable and efficient ways to detect these possibly devastating cracks will be imperative. In this study, we conducted a series of tests to determine whether these cracks could be exposed non-destructively through a technique proposed by Dr. Gary Wilson that is based on examining the forms of responses of metal to vibrational stimuli. Specifically, we expected to find nonlinear features in a cracked specimen through a process known as polyspectral analysis.

6. Edward Hou. Aerosol Agglomeration Transducers.

The application of transducers to the process of aerosol agglomeration involves matching desired electrical and mechanical parameters to a viable transducer design. The current attempt is to design transducers, which are devices that change energy from one form to another, that will create acoustical fields causing submicron aerosol particles, dispersed throughout a gaseous medium, to agglomerate and fall out. The process of acoustic wave motion may be useful in various pollution clean-up applications by reducing the mean particle size of discharged gases. For example, a driver transducer connected to the throat of an acoustic horn may efficiently change electrical energy into acoustical energy, which is necessary to stimulate the agglomeration process.

7. Mokhtar Maamar-Tayeb. Passive Detection and Localization of Acoustic Sources Using the Hough Transform and Broadband Crosscorrelation.

The goal of this work is to passively detect and localize one or more acoustic sources using the Hough transform to analyze a broadband correlogram. This method treats the broadband correlogram as an image and tries to match the observed delay curve with the large set of candidate template curves in order to estimate the parametrization of the observed delay curve. Due to the nature of the delay curve parametrization, estimation of these parameters

is equivalent to detection and localization of the acoustic sources shown on the broadband correlogram.

8. Anna Mitros. Measurements of Source Level in a Reverberant Underwater Environment.

When taking sound measurements, scientists are often faced with the problem of coherent noise, particularly surface and bottom reflections. While other sounds can be filtered out to yield a relatively clear signal, reflections do not vary in frequency from the source signal and cannot be filtered. Admittedly, in known environments it is possible to mathematically determine sound path and magnitude to account for interfering reflections. When taking data in an unknown or irregular environment, or when dealing with a small tank with numerous reflections, such a procedure can be extremely time consuming, if not impossible. An alternate method of measuring source levels that would account for coherent noise in such a reverberant environment would be greatly beneficial. The objective of this project is to find such a method and utilize it to estimate the free-field monopole intensity at one-meter radius and to then convert that intensity to the equivalent mean square pressure.

9. Jamie Margaret Shorey. Construction of a Parabolic Reflector from a Spinning Liquid.

When a container of liquid is rotated at constant speed, a combination of centrifugal and gravitational forces causes the surface of the liquid to take on a concave parabolic shape. If the liquid is one that hardens, such as epoxy, the paraboloidal surface becomes permanent. A dish with an optically and acoustically reflective surface is thereby produced simply and inexpensively. The purpose of this experiment is first to generate an acoustic reflector using the aforementioned technique, and then to compare acoustical data taken from both a machined aluminum reflector and the epoxy reflector to determine if unexpected results in data taken from the metal reflector are caused by defects or imperfections in the surface.

10. Nicholas Tornow. Audio Simulations of Sonar Bottom Backscattering Using Head-Related Transfer Functions.

As technology continues to develop, manipulation of large amounts of data becomes ever simpler. One field, which until recently was too complex to explore thoroughly, is a human's auditory perception of three-dimensional space. Although humans do not have highly developed spatial recognition capabilities, some directional interpretation is possible. By filtering sounds through head-related transfer functions (HRTF) and playing them through headphones, one can match the signals as they would naturally be received at the ear canals, and therefore can convince the ears that the sound was emitted from a certain direction and distance. The effect, although not perfect, is accomplished through small time delays between right and left ears with phase and amplitude shifts at different sound frequencies. The capability of simulating spatial sound sources allows one to more fully understand the environment. In nature small and discrete sounds are emitted as the wind blows through the trees and grasses. Humans have learned to interpret these sounds and thus get a feel for their surroundings, even in the dark. In the underwater environment, humans are completely in the dark. Sonar allows humans to visually simulate the image of their surroundings. Augmenting a sonar with an auditory background can make the situation more natural and understandable. Work has been conducted to use three-dimensional sonar data of the seafloor, taken underwater at ultrasonic frequencies, to simulate the echoes a human observer might hear if the seafloor were in air and the transmitted pulse were an audible frequency. This report represents a summary of the work conducted.

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REFERENCES

1. ARL:UT proposal Ser P-1612, dated 6 July 1993, from Dr. F. Michael Pestorius, ARL:UT Director, to Dr. Mohsen Badiey, ONR Code 324OA, for $400,000 for the performance period 1 October 1993 through 12 months.

2. ARL:UT proposal Ser P-1612(Rev.), dated 9 March 1994, from Ms. Patti B. Hall to Dr. Mohsen Badiey, ONR Code 324OA, for substitution of tasking.

3. ARL:UT proposal Ser P-1629, dated 17 February 1994, from Dr. F. Michael Pestorius, ARL:UT Director, to Dr. Jeff Simmen, ONR Code 324OA, for $8,500 for the performance period 1 October 1993 through 12 months.

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